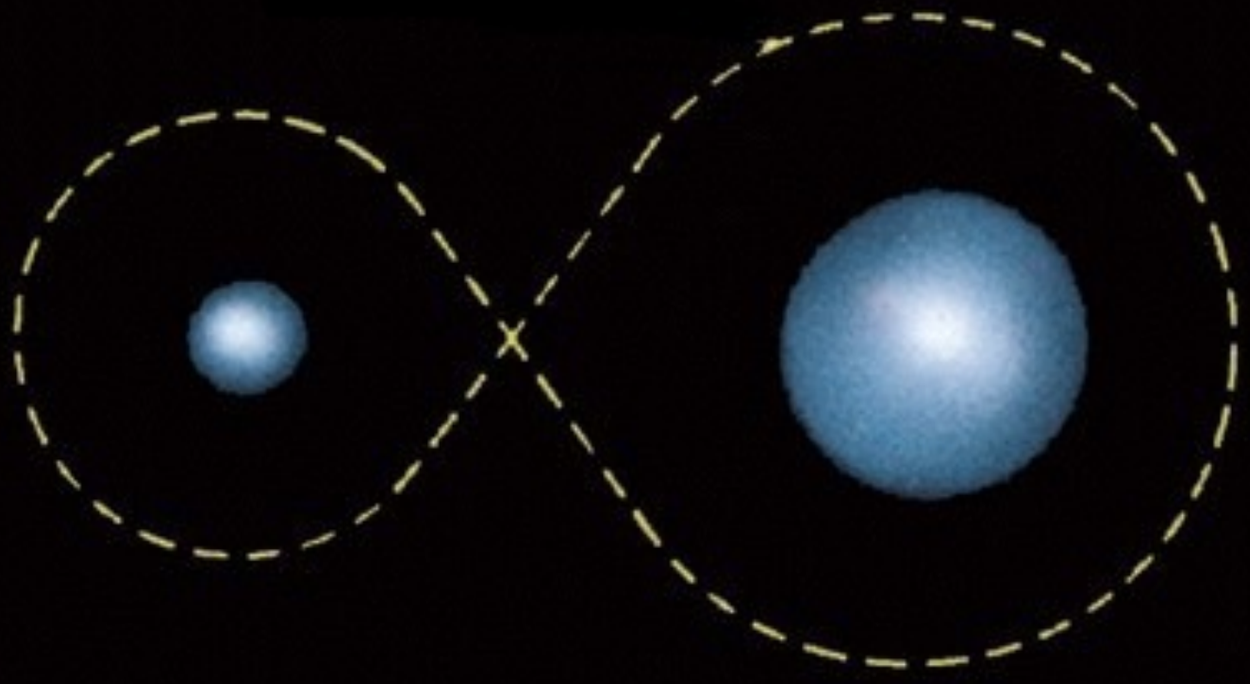
The Discovery and Characterisation of Binary Central Stars of PNe

David Jones (djones@iac.es)

BINARY EVOLUTION

COMMON ENVELOPE



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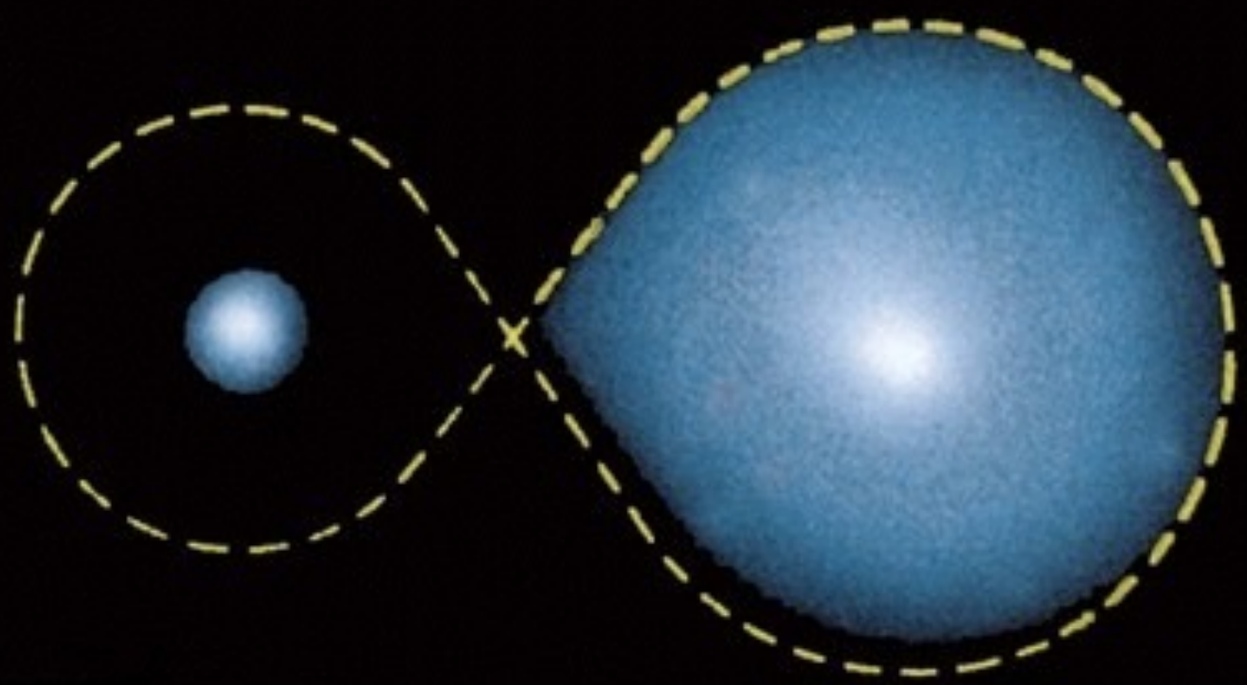

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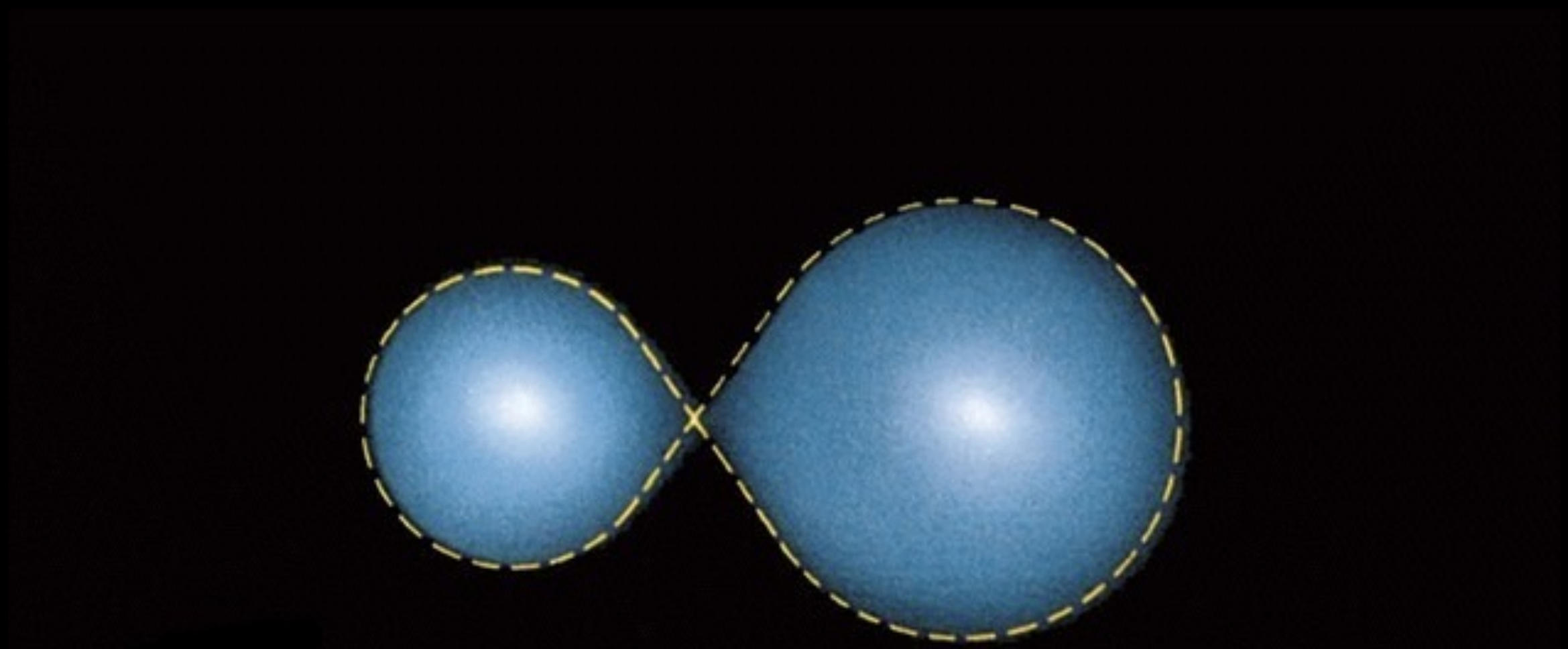

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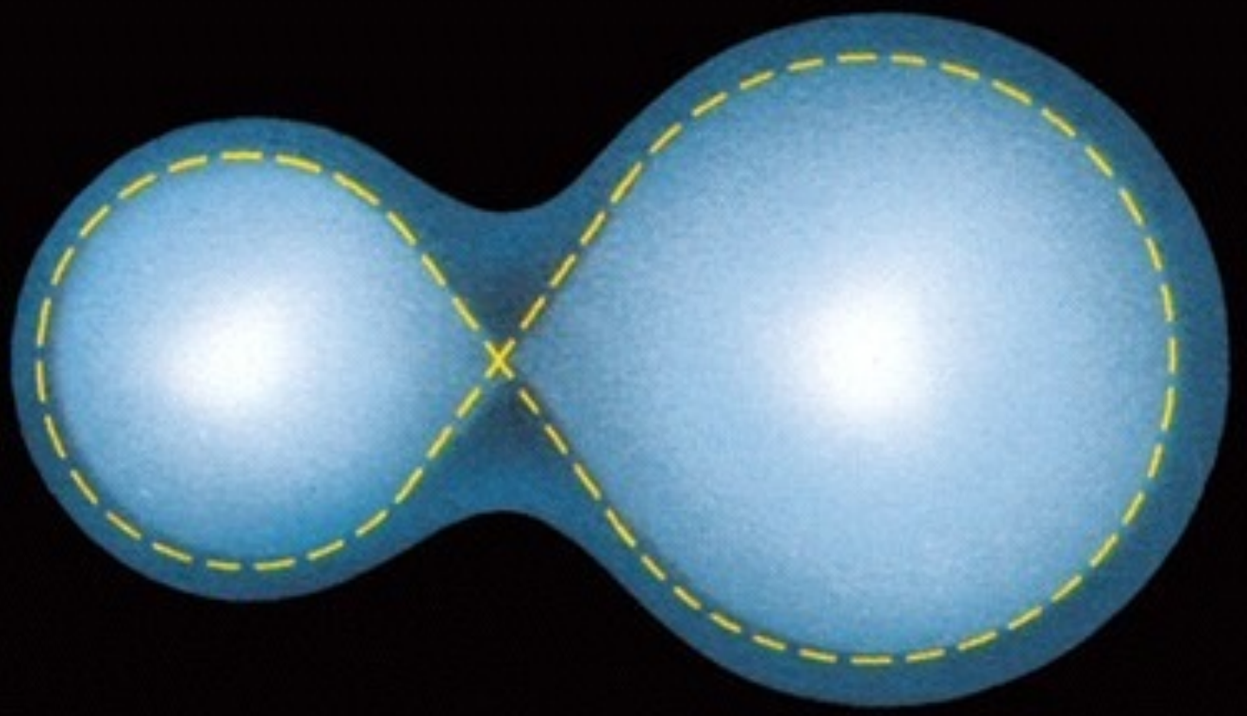
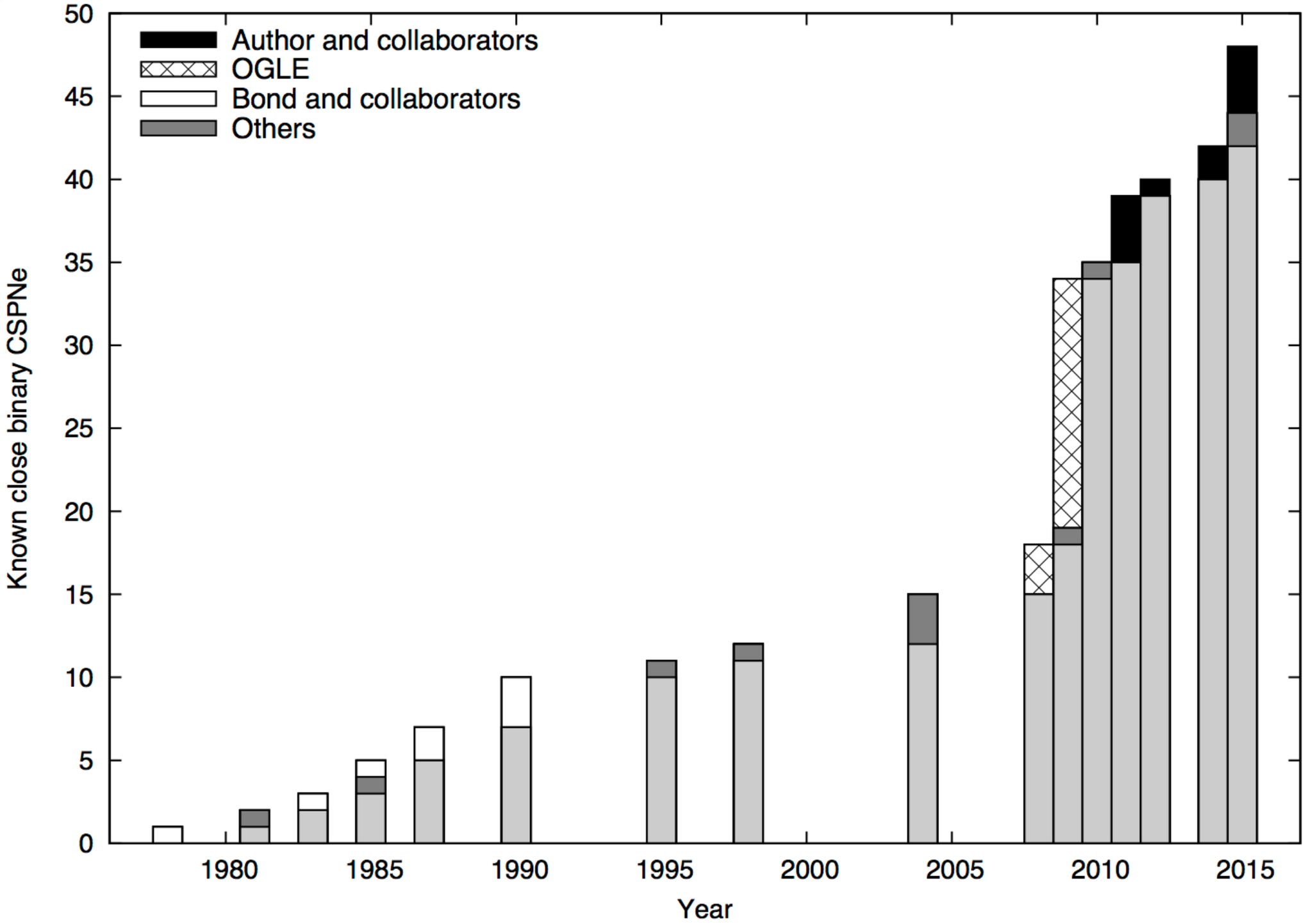


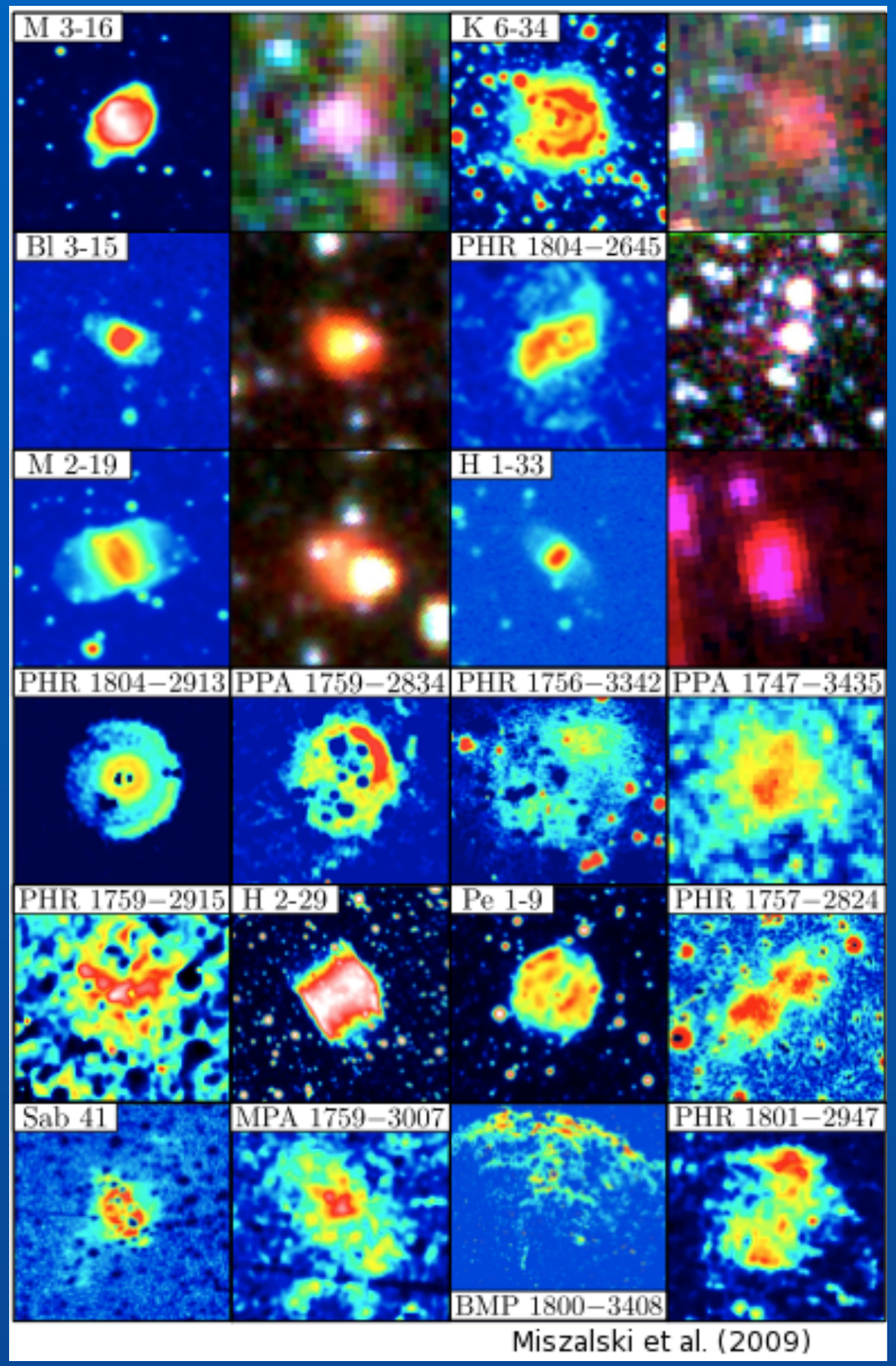


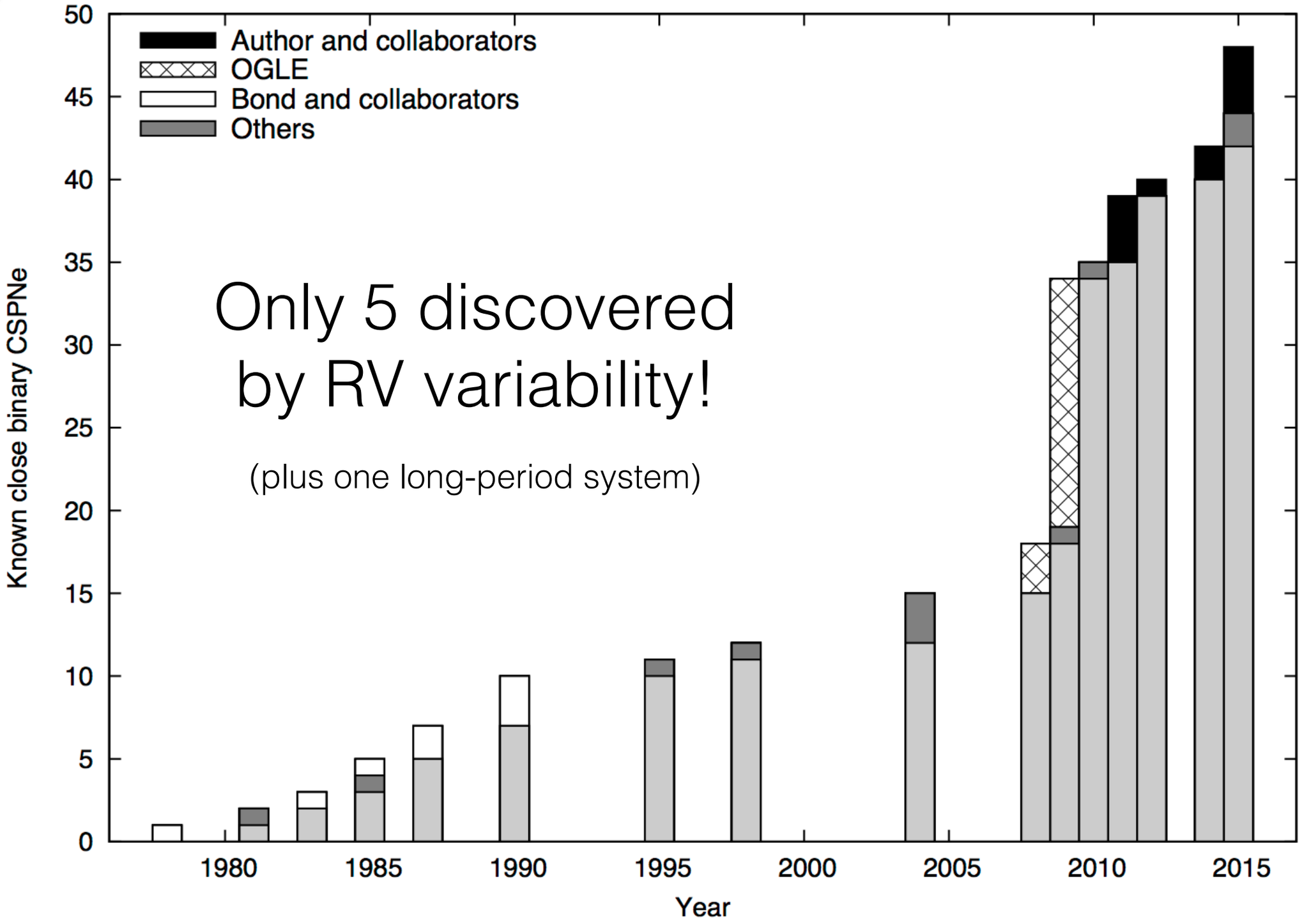
drdjones.net/bCSPN for a full (regularly updated) list

OGLE Survey

Miszalski et al. (2009a,b)

- More than doubled the sample
- i-band survey of the Galactic bulge
- Close-binary fraction of ~20%
- Clear confirmation of a binary pathway for PN formation



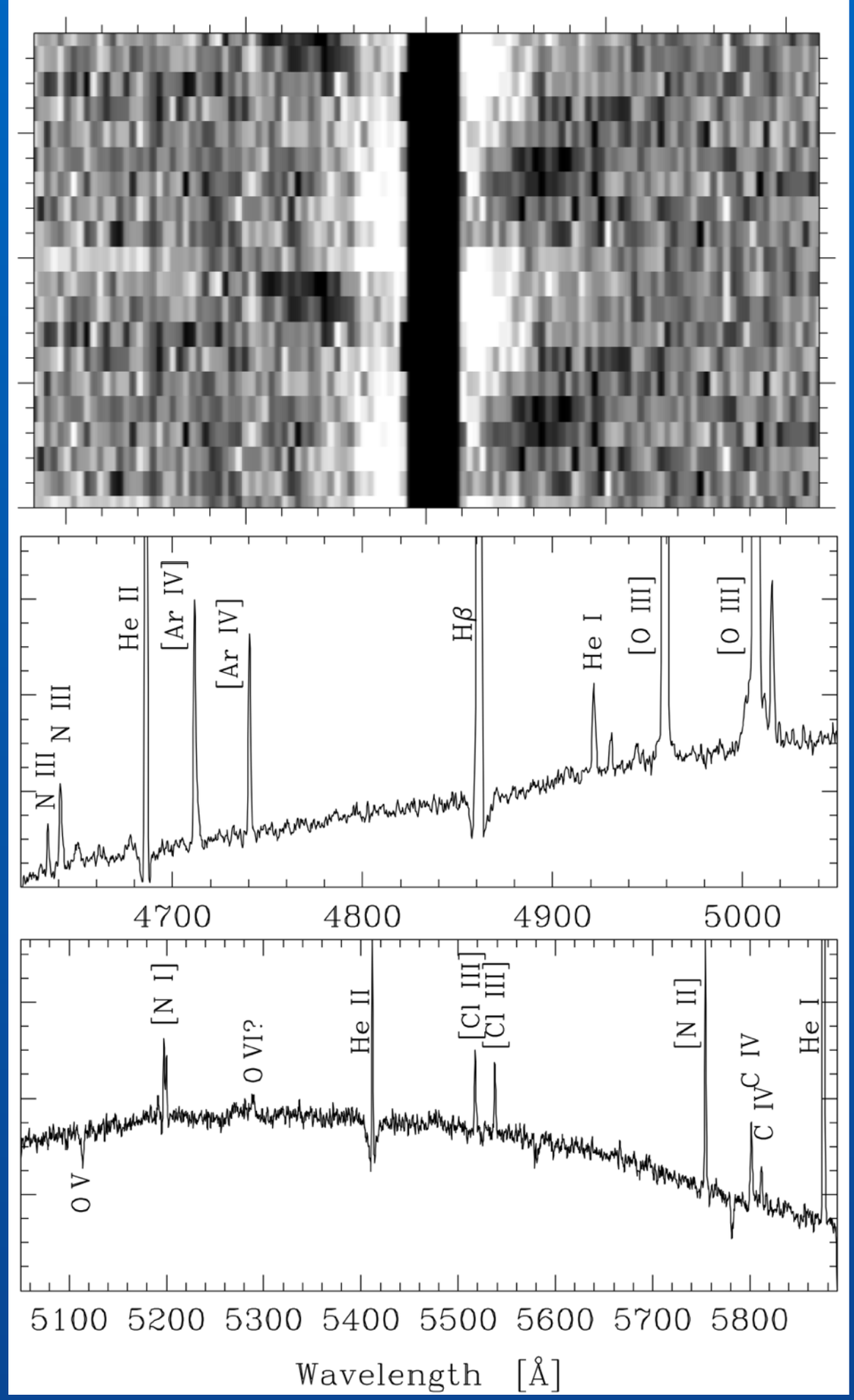


Only 5 discovered by RV variability!

(plus one long-period system)

RVs are difficult!

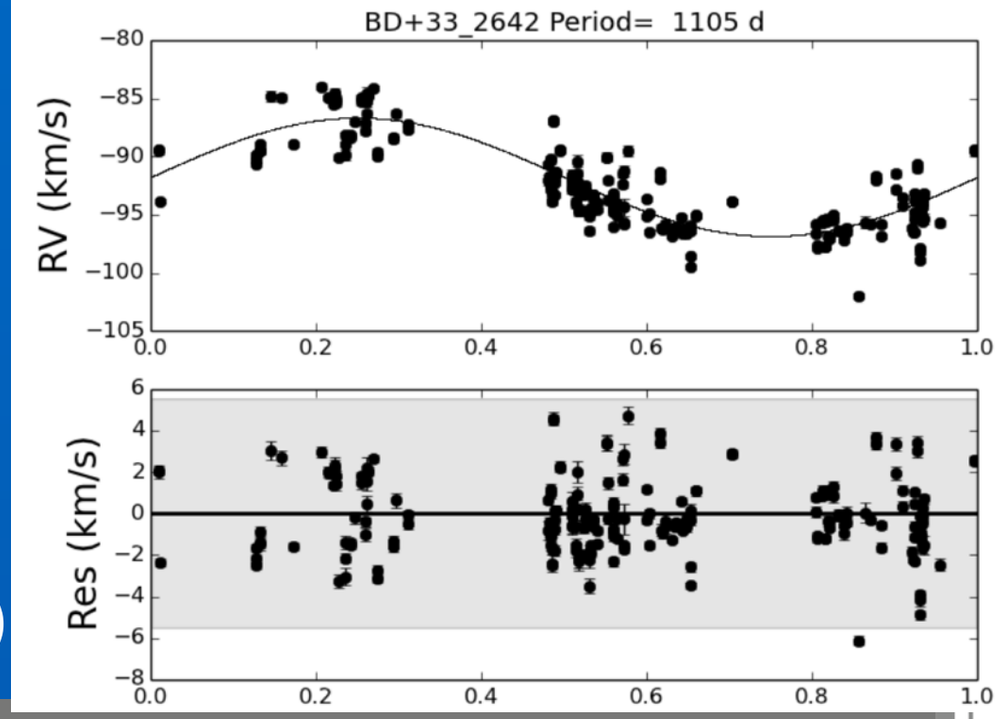
- Need good spectral resolution
- Big telescope? Lots of time for “fishing”
- Nebular contamination is a problem
- On some level everything is variable!



Jones et al. (2015, A&A, 580, 19)

… but very important!

van Winckel et al.
(2014, A&A, 563,10)



REPORTS

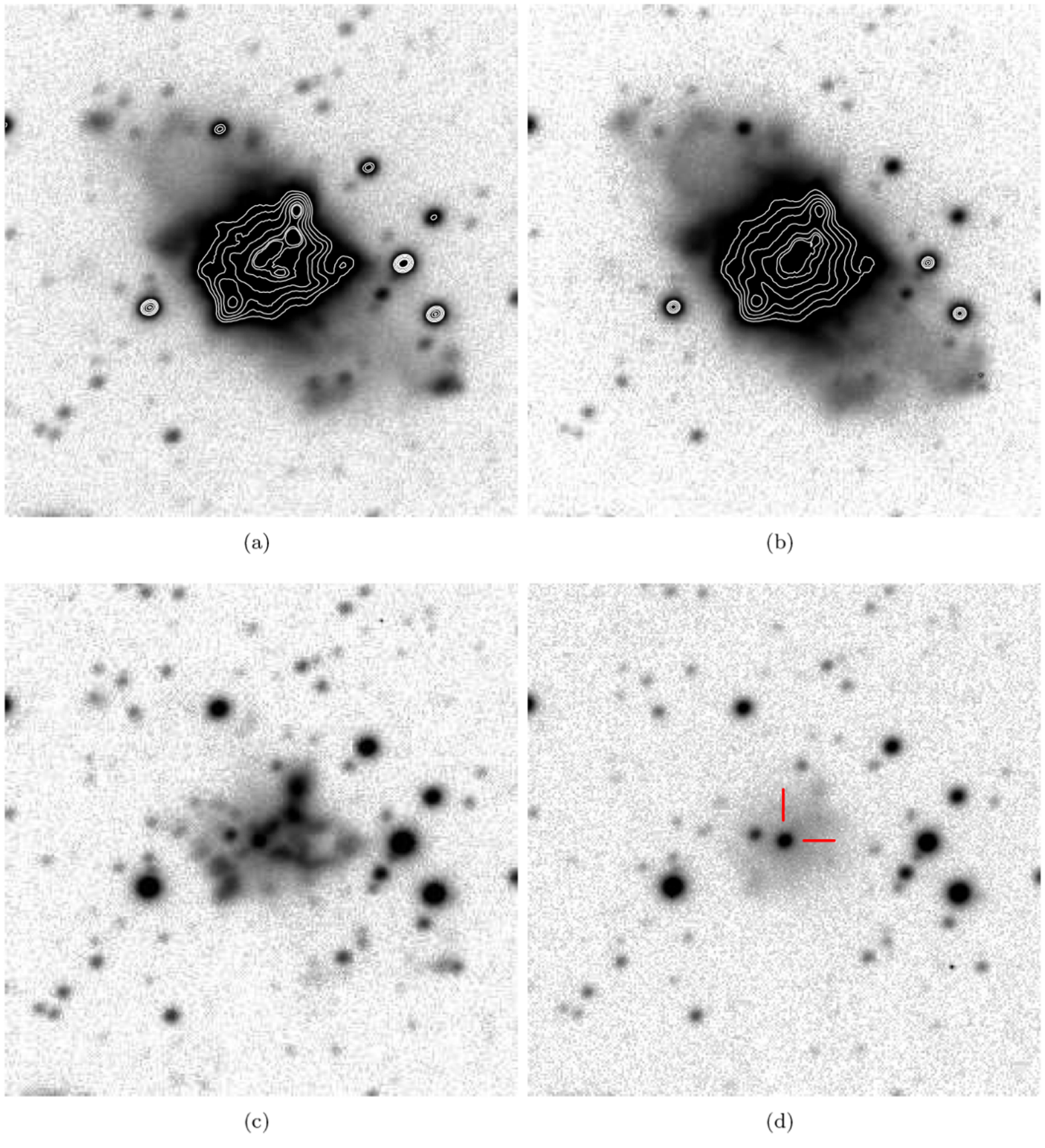
- Some systems won't be photometrically variable
  - Long periods
  - Double degenerates

An Interacting Binary System Powers Precessing Outflows of an Evolved Star

Boffin et al.
(2012, Science,
338, 773)

Nebular Contamination

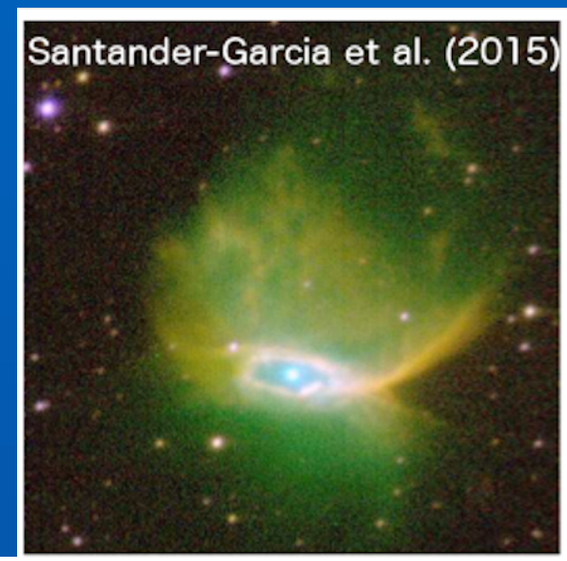
- i-band (and Str y) quite effective (see OGLE)
- Some need narrowband (Hβ-continuum)
- Image subtraction very good but not “on-the-fly”

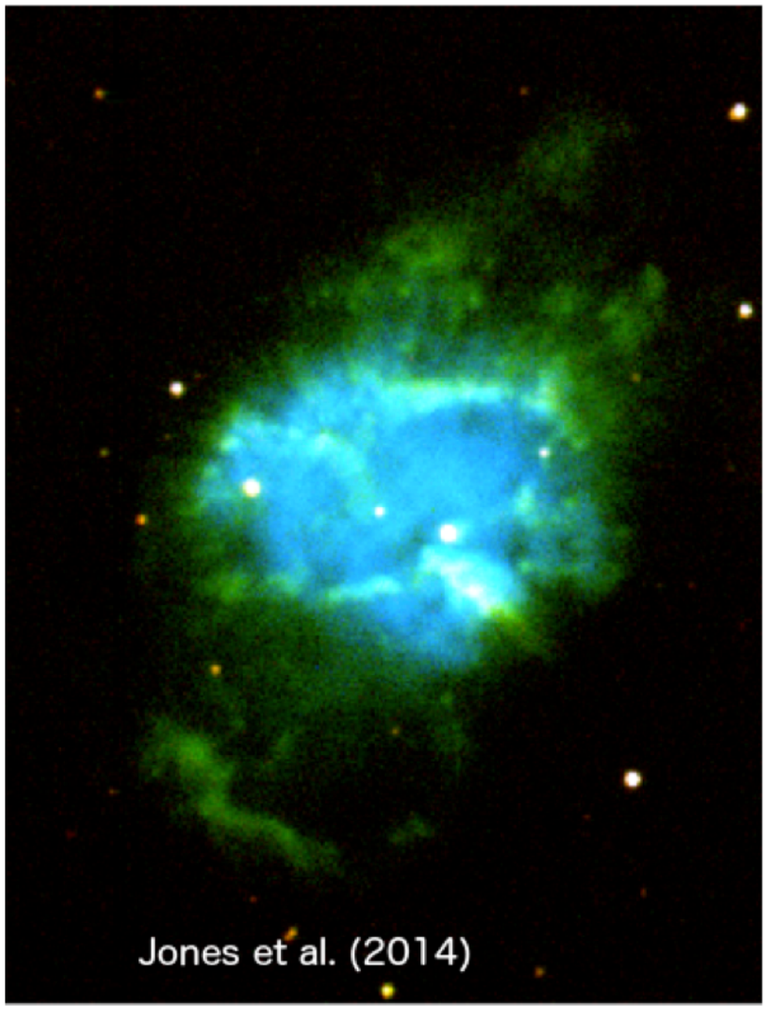


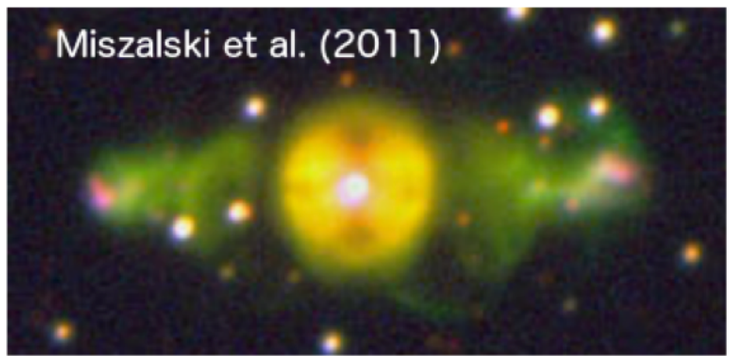
Jones et al. (2015, A&A, 580, 19)

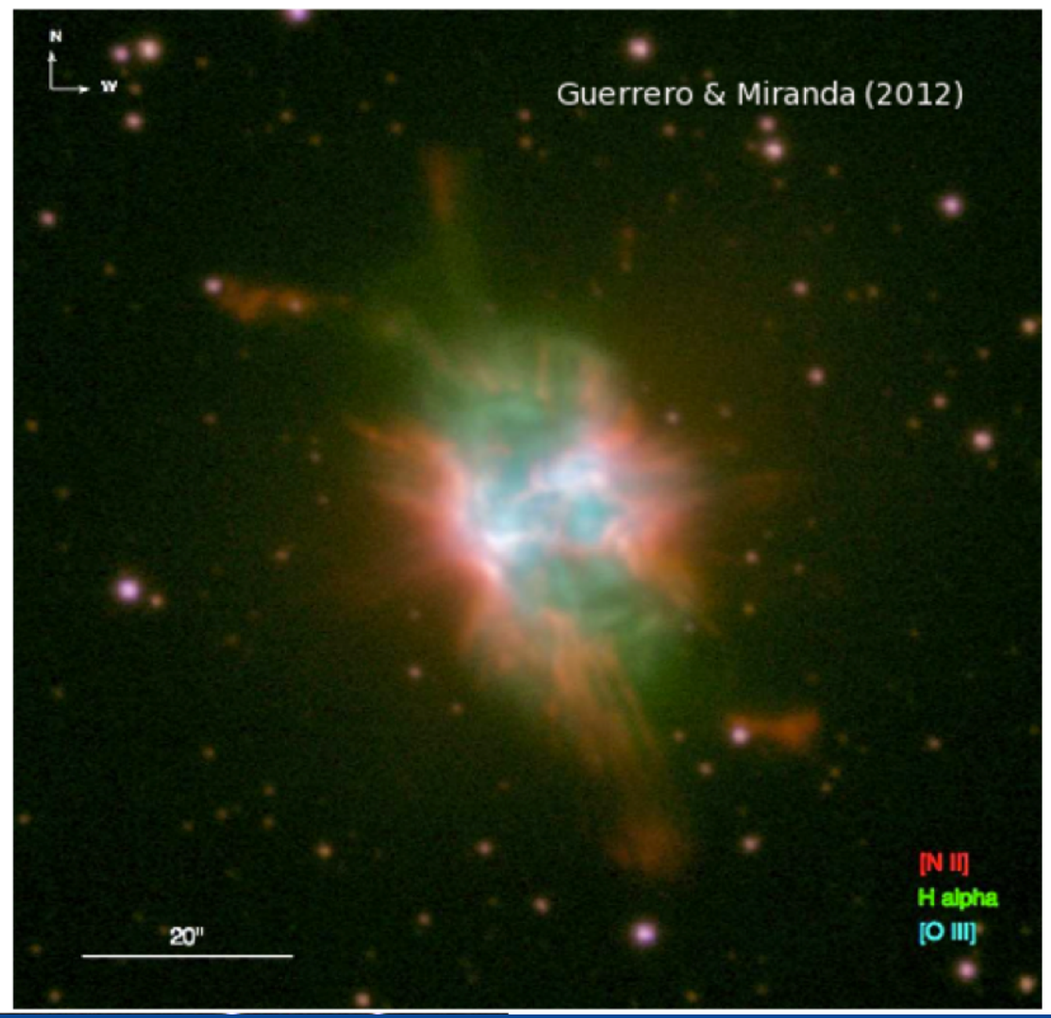
Recent efforts have focused on pre-selected "good" candidates

- Filaments
- Knots
- Rings
- Jets



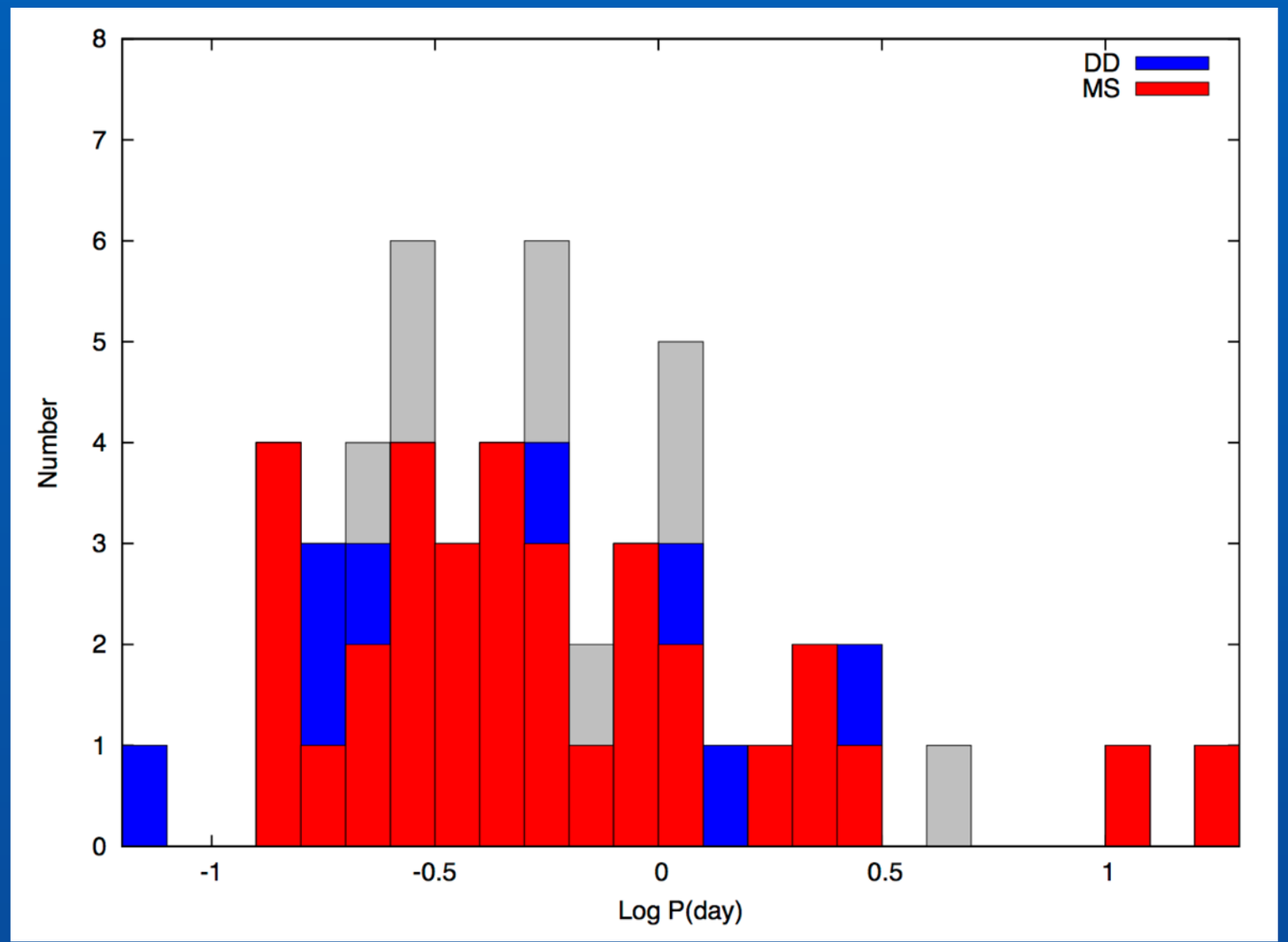


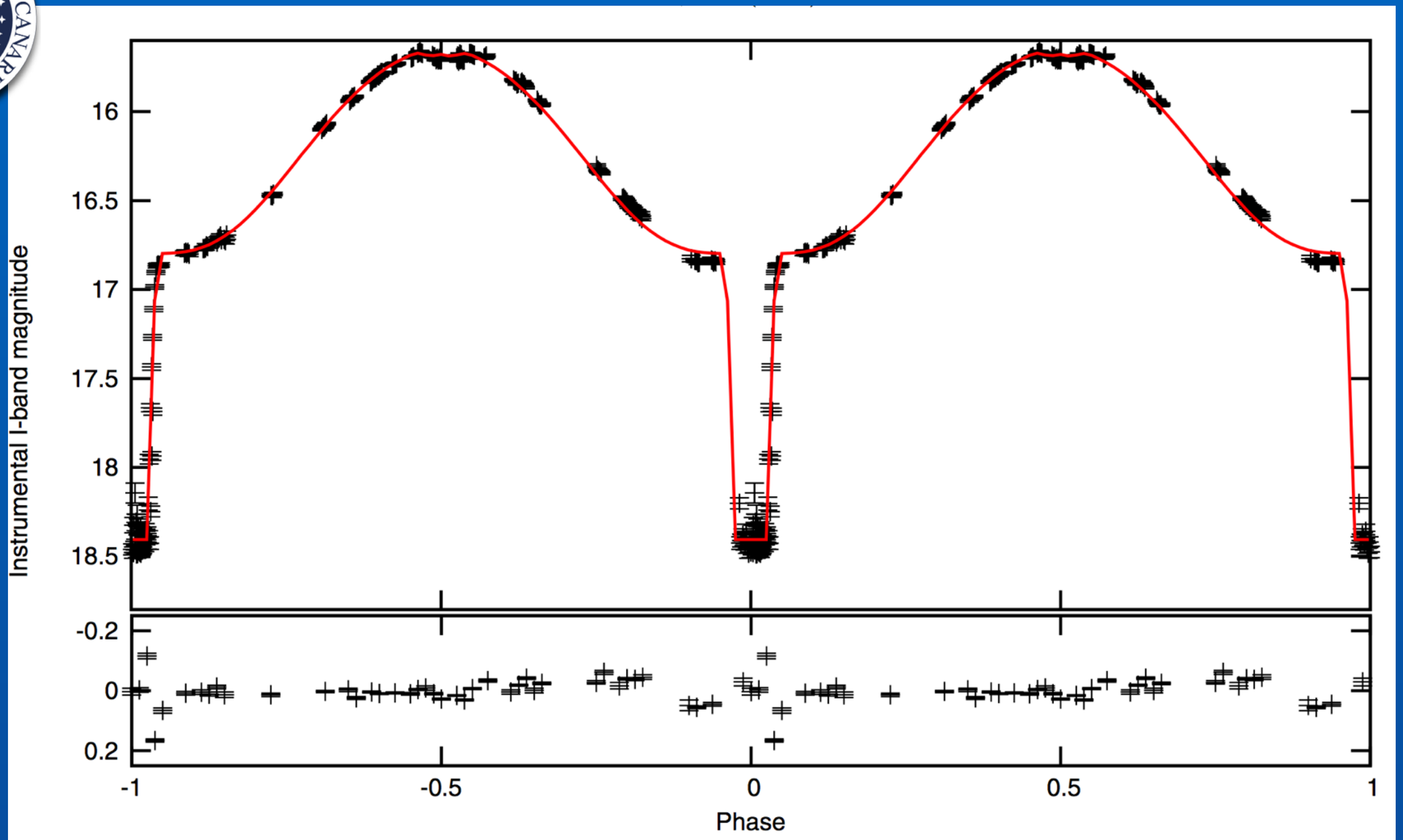




Very successful, but statistics are difficult

- Biased?
  - Spectral types
  - Period range
  - Age
  - ?
- Need for rigourous survey
  - 2 kpc volume-limited sample (Todd Hillwig, David Frew, myself)
  - Will be best measure of binary fraction to-date





Characterisation really needs RVs

(and eclipses and photoionisation modelling of host PN)

Hen 2-11 Jones et al. (2014, A&A, 562, 89)

Characterisation is hard!

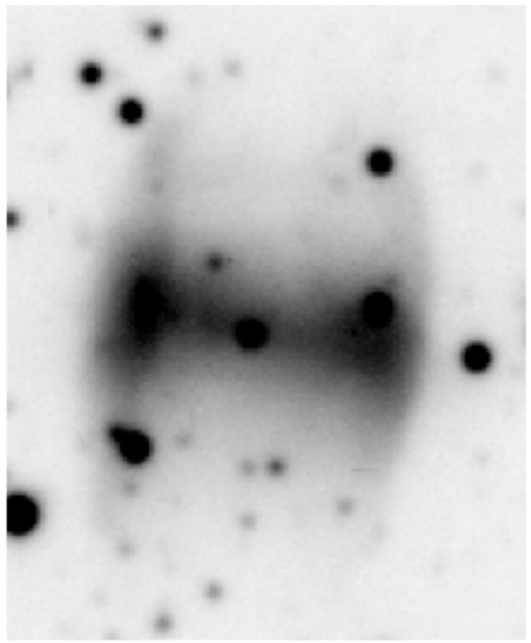
Nebula	Period (day)	M_{CS} ($M_\odot$)	R_{CS} ($R_\odot$)	T_{CS} (kK)	M_S ($M_\odot$)	R_S ($R_\odot$)	T_S (kK)
Abell 46	0.47	0.51±0.05	0.15±0.02	49.5±4.5	0.15±0.02	0.46±0.02	3.9±0.4
Abell 63	0.47	0.63±0.05	0.35±0.01	78±3	0.29±0.03	0.56±0.02	6.1±0.2
Abell 65	1.00	0.56±0.04	0.056±0.008	110±10	0.22±0.04	0.41±0.05	5.0±1.0
BE Uma	2.29	0.70±0.07	0.08±0.01	105±5	0.36±0.07	0.72±0.05	5.8±0.3
Ds 1	0.36	0.63±0.03	0.16±0.01	77±3	0.23±0.01	0.40±0.01	3.4±1
Hen 2-155	0.15	0.61±0.06	0.31±0.02	90±5	0.14±0.06	0.30±0.03	3.5±0.5
Hen 2-428	0.18	0.88±0.13	0.68±0.04	32.4±5.2	0.88±0.13	0.68±0.04	30.9±5.2
NGC 6026	0.53	0.57±0.05	1.06 ±0.05	38±3	0.57±0.05	0.05±0.01	146±15

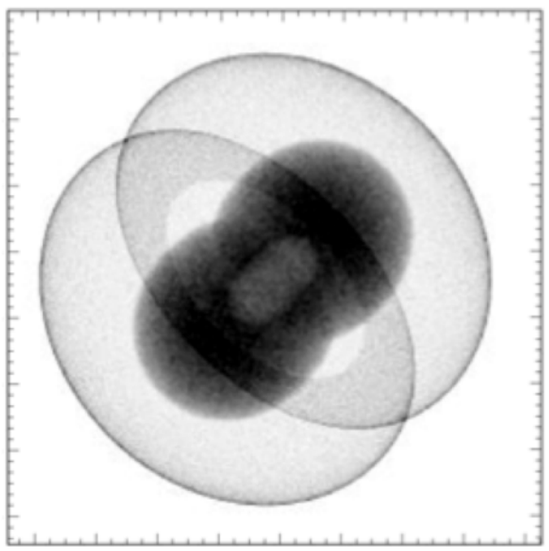
Only 8 systems properly constrained

But quite a few others have good estimates of (at least) the orbital inclination…

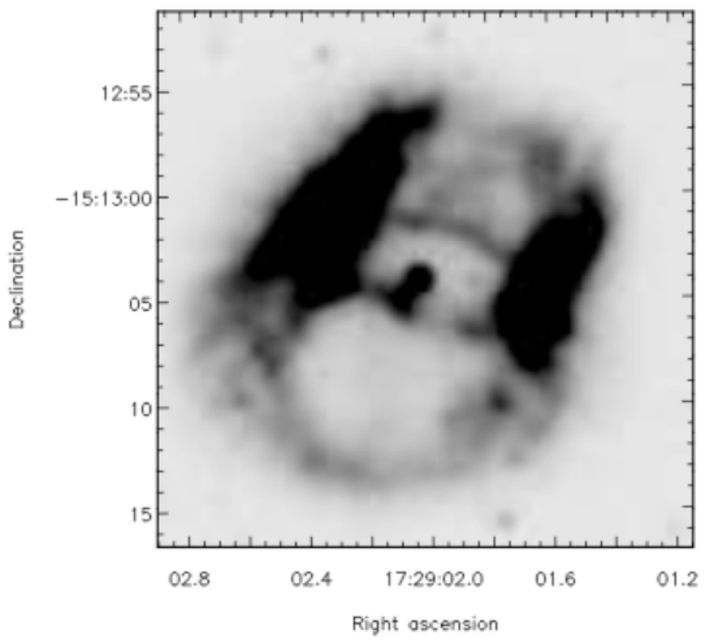
Jones et al. (2015, A&A, 580, 19) and references therein
Jones et al. (2014, APNVI)

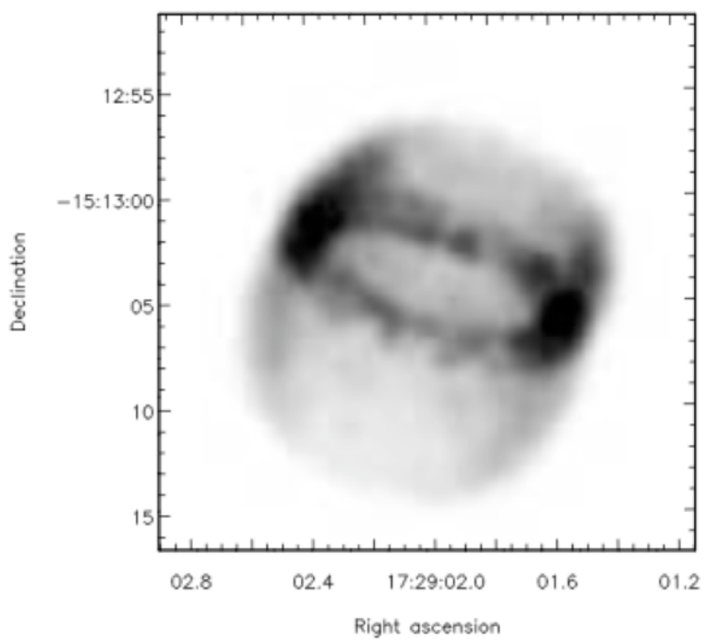
Binaries definitely shape PNe





Orbital planes are
ALWAYS
perpendicular to
nebular symmetry axes





Inflated Secondaries!

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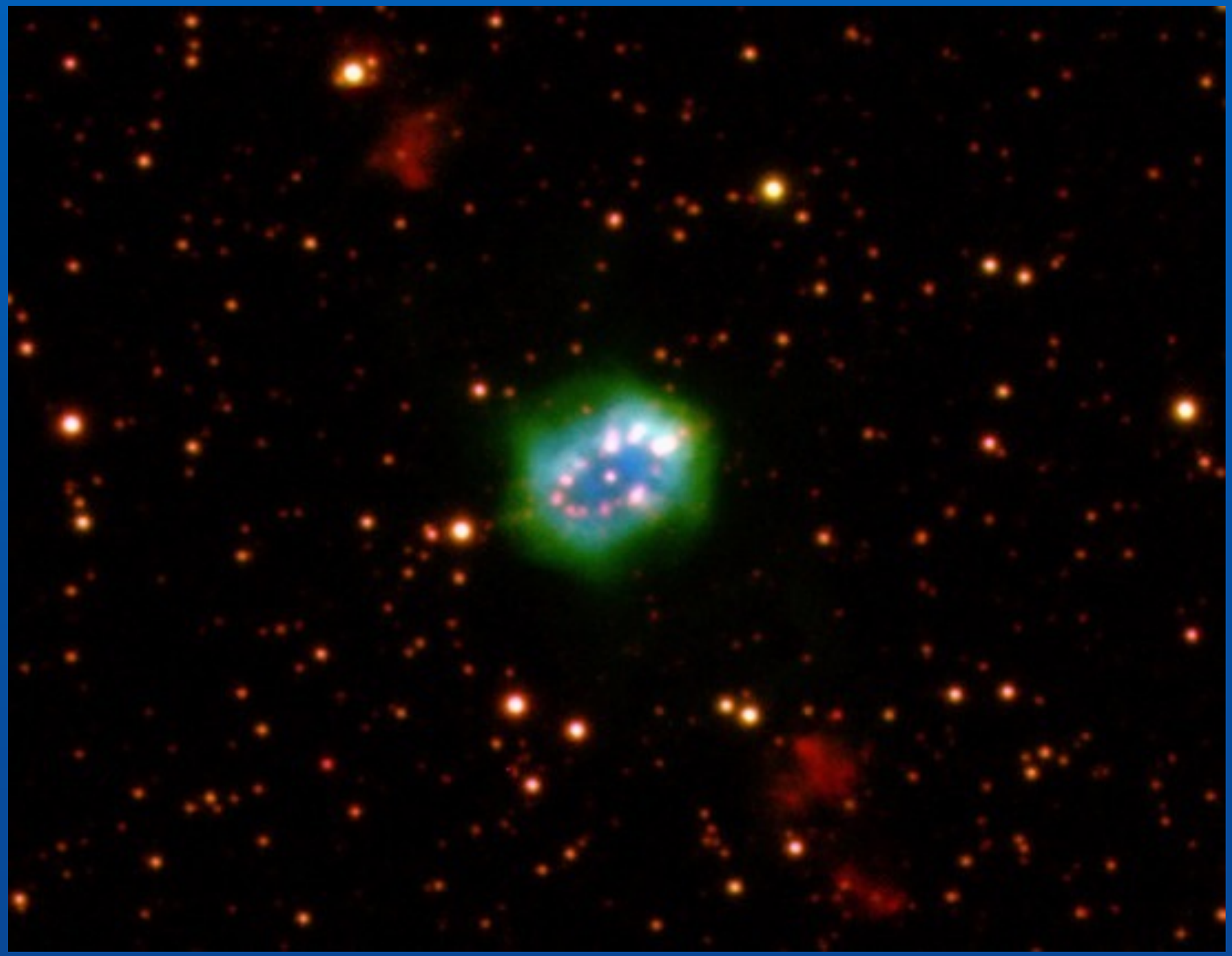
Only 8 systems properly constrained

2 Double-degenerates (incl. best SN Ia candidate to-date)
6 Main sequence companions - all inflated w.r.t. ZAMS

Jones et al. (2015, A&A, 580, 19) and references therein

Evidence of Mass Transfer



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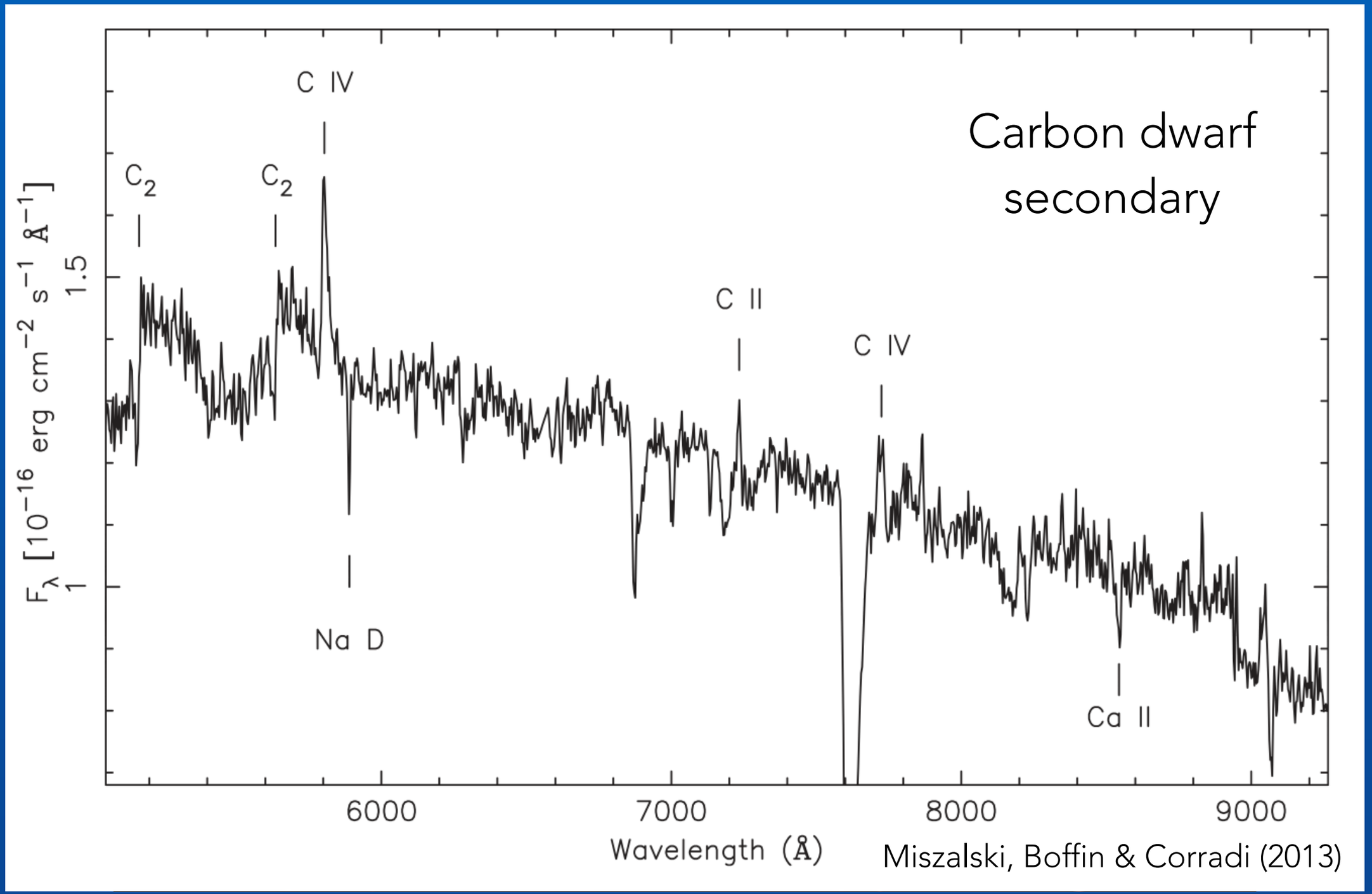

Carbon dwarf secondary

Miszalski, Boffin & Corradi (2013)

Jets forming before CE

PN	Neb. age (yrs)	Jet age (yrs)
Fg 1	2000	2500-7000
Necklace	1100	2400
ETHOS 1	900	1800
Abell 63	3500	5200

Jones (2014, APNVI)

Summary

- Discovery and characterisation of bCSPNe is a painstaking and time-consuming process
  - but worth doing!
- (Some) PNe are definitely shaped by binary stars
- bCSPNe are key to understanding close binary evolution (and other phenomena - see Romano's talk)
  - Too many double-degenerates? (Too many short period binaries?)
  - Pre-common-envelope mass transfer